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Management of Swisskarst

Waters in Switzerland

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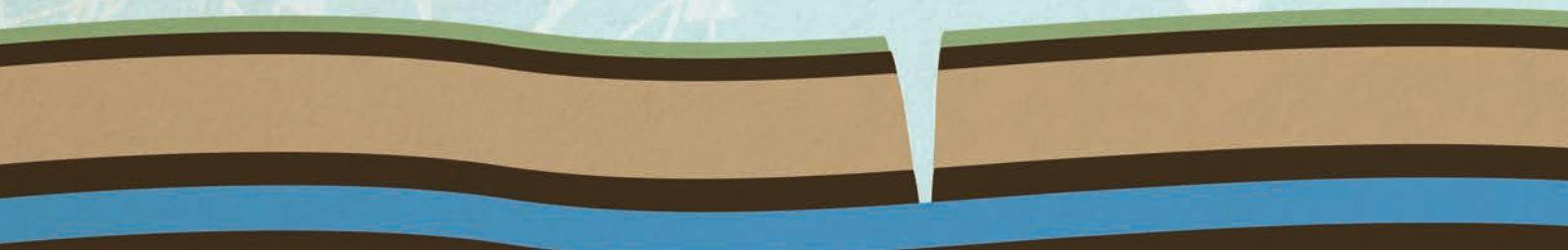
Karst **aquifers**

Passionate about the poorly understood karst landscapes and aquifer systems, **Dr Pierre-Yves Jeannin** introduces SwissKarst – the interdisciplinary project that aims to characterise karst aquifiers in Switzerland

Could you provide an insight into your career as a hydrogeologist? How has the Swiss Institute for Speleology and Karst Studies (SISKA) facilitated the study of karst?

During the course of my PhD and postdoc I realised that the state of karst research is much more advanced than knowledge concerning the practical management of these areas. This requires an interdisciplinary approach, with input from biologists, archaeologists, geomorphologists, etc., in addition to hydrogeologists. I consequently created SISKA with the aim of improving the management of the karst environment in Switzerland.

SISKA is a non-profit foundation covering most topics related to karst. Starting with just two people – a designer and a hydrogeologist – the aim was to improve the knowledge and management of karst regions via education and research as well as practical and consulting activities. SISKA grew by about 10 per cent annually and its expansion involved the further diversification of our interests with the addition of three geologists, four hydrogeologists and two archaeozoologists. The equilibrium between profitable and non-profitable activities is always difficult, especially considering that subsidies from the state tend to decrease. After 13 years, the importance of a competence centre on karst in Switzerland is clear, and I am confident that SISKA will continue to grow for years to come.



Underground **unknowns**

A Swiss team of interdisciplinary researchers is systematically and pragmatically characterising the nature of karst aquifers to enable their effective, efficient and safe management

KARST ENVIRONMENTS ARE characterised by typical surface features such as cenotes, sinkholes or dolines, and are formed by the action of mildly acidic water on weakly soluble bedrock such as limestone or dolostone. The water slowly dissolves the rock along fractures or specific planes of weakness, which enlarge over long periods of time, creating a cavernous underground network through which water drains. The lack of surface water in the form of lakes, streams or rivers reduces the volume of the available water facilities for local agriculture, but the groundwater within karst aquifers represents a significant resource which may be comparable to all Swiss lakes.

However, there are potential problems with the use of karst groundwater as a source of drinking water or for agricultural purposes. Its rapid infiltration into the ground, and flow through dissolution channels, means it bypasses the usual filtering processes that occur in a non-karst aquifer. Thus karst groundwater is frequently polluted. These issues, along with the fact that the water catchment associated with karst landscapes is largely invisible and thus difficult to manage, engenders a strong need to more fully characterise and model the water within these regions to gauge the volume of water they contain, and understand their geographical scale and internal structure, as well as how this affects input, output and flow through the system.

A project entitled 'SwissKarst: Towards a sustainable management of karst waters in Switzerland', led by Dr Pierre-Yves Jeannin from the Swiss Institute for Speleology and Karst Studies (SISKA) is exploring these issues. Having developed an interest in karst environments whilst caving at the age of 15, Jeannin embarked upon a career as a hydrogeologist, and is devoted to understanding these complex underground systems and how they are influenced by external factors such as a changing climate, urbanisation, agricultural exploitation and increased utilisation. This is important as karst groundwater supplies approximately 18 per cent of Switzerland's water, and cities such as Montreux, Vevey and La Chaux-de-Fonds exclusively depend on karst water for their drinking supply.

THE KARSYS APPROACH

SwissKarst aims to provide a concrete and pragmatic documentation of karst aquifers in Switzerland in order to improve their management". The project's findings already contribute to the continued integrity of karst groundwater and have developed a better understanding of the water systems in these regions. The resulting documentation covers issues related to drinking water, flood hazard assessment and the impact of human

What are karst waters?

Karst waters refers to a specific type of groundwater that flows through soluble rocks, ie. mainly limestone, dolomite, salt or gypsum. Groundwater in these rock formations flows through a network of natural dissolution pipes, leading to the formation of caves, and is able to discharge a huge amount of water in a short space of time. This network is fed by a slow-flow component of water moving in fissure and matrix media, and by a quick-flow component draining rain infiltration almost directly towards the conduit network. The flow organisation (structuration) is thus complex at the scale of the massif. Such 'dual' behaviour and the structure of karst aquifers induce specific management questions.

Do karst waters lack sustainable development?

Due to the absence of a recognised and pragmatic approach, and a dearth of teaching of karst hydrogeology in geosciences and engineering, these aquifers remain poorly investigated or even ignored, despite the fact that they cover more than 20 per cent of the emerged surfaces of the Earth and have been exploited for decades. Managers are aware of their limited knowledge and are increasingly interested in taking a better approach. Our project is therefore well recieved among stakeholders concerned with karst.

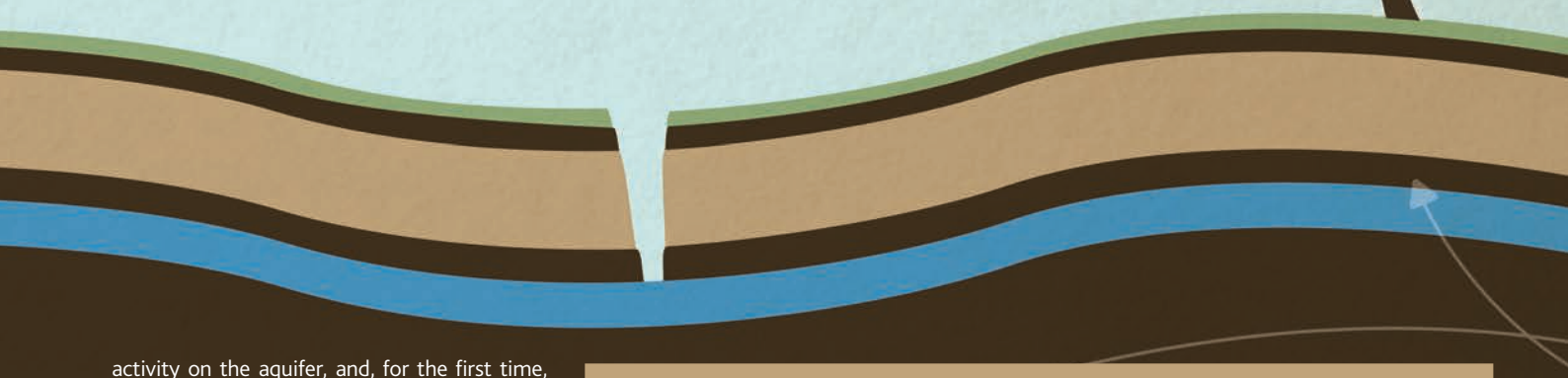
Karst groundwater represents 80 per cent of the Swiss groundwater reserves and likely around 50 per cent of the annual groundwater renewable resources. These aquifers have to be fully integrated in the framework of a sustainable water management system in Switzerland.

Which 3D models are employed in your approach and how will they be combined with geological and hydrological data?

We mostly combine existing data sources in order to understand groundwater flow. Some geological layers are assumed to be karstified, ie. highly permeable, and others (eg. shales) are impervious. The 3D geological model sets the geometry of these layers. Water is assumed to infiltrate and form groundwater bodies in karstified rocks, and to be dammed by less pervious ones. Springs are the outflow of the karstified layers, meaning that the whole karstified volume, below the level of the springs, is full of water. The model is built by considering the geometry of karstified rocks, and the position of both the outlets (springs) and the expected recharge areas (outcropping karstified rocks). Variations in groundwater level can be introduced into the 3D model. This may evidence changes in water flows between low and high water conditions.

Can you outline the expected far-reaching effects of sustainable karst aquifer management?

Multiple benefits can arise from a better understanding of karst systems and their sustainable management, including preserving and/or restoring the exploited drinkable water quality by optimising the extraction processes on the catchment; ensuring the safety of the buildings and civil engineering works both surrounding and within the karst landscape; and finally, contributing to the efficiency of energetic exploitation in karst aquifers such as hydroelectricity or geothermal devices. Improving the knowledge and the management of this groundwater resource and its functioning will surely contribute to the reduction (or optimisation) of environmental and economic sustainable costs.



activity on the aquifer, and, for the first time, considers these striking regions at a national scale using a systematic approach. To achieve this, the team has developed the KARSYS approach which seeks, firstly, to track the flows of the groundwater and identify where the main sinks and springs are; and secondly to characterise the volume and geographical dimensions of the recharge/discharge areas and approximate discharge rates. This information is incorporated into a 3D geological model and coupled with consistent karst hydrogeological data to construct a representation of the karst groundwater system. The model includes the geological boundaries of the karst systems; a description of how the water is infiltrated into the ground across the catchment areas; the geometry of the aquifer and water contained within; and a sketch of the main hypothesised paths of water flow. This information is important so that the water supply from the karst system can be exploited as a water source, but in a sustainable manner to retain its integrity (water quality, sufficient quantity).

This user-friendly model is already being used by a wide variety of stakeholders to evaluate how various scenarios of exploitation or management – underground infrastructures, polluting activities or use of water supply, etc., will impact characteristics of the system, such as the capacity of the groundwater storage, physical geological state and future sustainability, and predict the hydrogeological response to human interventions such as underground infrastructures, polluting activities or geothermal probes.

Throughout the course of SwissKarst, the KARSYS approach has been applied to many major karst aquifers in the country. The outcome is a 3D view of the respective systems, as well as map views, profiles, and an 'identity card' summarising the major characteristics of the individual hydrogeological flow systems. An example of region-wide KARSYS application is in the Bernese Jura region, an area of around 540 km^2. This region of Switzerland counts more than 50,000 inhabitants who are dependent on karst water for their drinking supply and for industrial processes. This study was able to increase understanding of flow mechanisms at a regional scale, as well as considering the interactions between adjacent or remote systems and defining the main subterranean flow paths. 17 distinct karst systems were successfully identified and characterised, providing a better and 'easy to show' understanding of groundwater flow systems in the region than any previous reports.

The SwissKarst project has successfully performed fundamental research to understand this complex and specific system as well as developing applied approaches and methods to characterise this landscape in real and modelled situations

SWISSKARST: TOWARDS A SUSTAINABLE MANAGEMENT OF KARST WATERS IN SWITZERLAND

OBJECTIVES

To provide a concrete and pragmatic documentation of karst aquifers in Switzerland in order to improve their management

KEY COLLABORATORS

Arnauld Malard; **Jonathan Vouillamoz**; **Eric Weber**; **Urs Eichenberger**; **Demian Rickerl**, SISKA

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DR PIERRE-YVES JEANNIN grew up in Neuchâtel in Switzerland where he studied Geology for four years and Hydrogeology for two. He later obtained his PhD on karst hydrogeology. He performed a one-year postdoc in Tübingen (Germany) and a six-year postdoc in Neuchâtel as the leader of the karst research group. In parallel to this, he created the Swiss Institute for Speleology and Karst-Studies, which is a foundation rather than belonging to a University. Beginning with two positions in 2000, the Institute has now expanded to nine. Jeannin has published different papers (all on karst) in many international journals and is a reviewer for several of them.

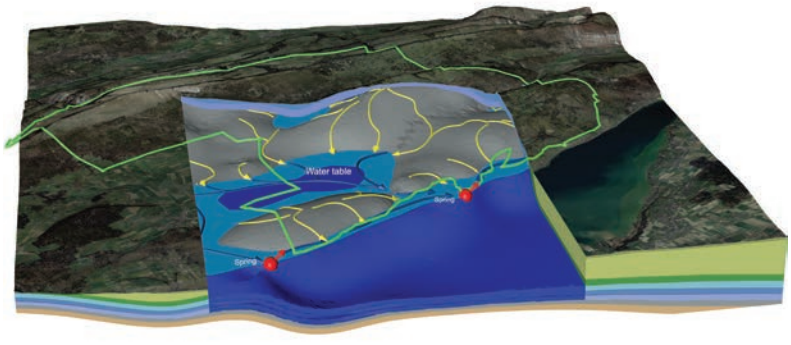
HAZARD PERCEPTION

Alongside developing and testing the KARSYS approach to characterising karst systems, Jeannin's team has also been working on KarstALEA – a method for predicting karst-related problems in civil engineering. While it is heavily based on the KARSYS system, it includes expanded functionality to consider the potential inherent hazards within karst media for engineers, geologists and other underground workers. These include: the presence of subterranean voids, which makes it difficult to construct underground supports; sediment, clump or collapse which can damage tunnelling machinery; and the large quantities of water often found flowing at high pressures that can present a safety hazard for workers.

The KarstALEA hazard analysis system involves three different stages. The first is an initial assessment of the karst massif, to determine whether or not there are any potential karst-related hazards. The second involves carrying out a KARSYS analysis, ie. building a 3D model of the karst system using data from geology and hydrogeology. Predictions with KarstALEA need further information about cave development and special geological surfaces along which dissolution preferentially develops. In this way, the system is fully understood and characterised before the construction phase can begin. However, this is not the end of the functionality of the KarstALEA method; along the construction, data are regularly acquired and the prediction model can be updated accordingly. This gives the model the best chance of being used to effectively solve engineering-related problems that arise during the work.

This approach is also applied in the prediction of karst-related hazards at ground surface, for example to assess the probability of constructing a building over an underground void.

In developing a fully characterised 3D model of karst systems, the SwissKarst project has successfully performed fundamental research to understand this complex and specific system, as well as developing applied approaches and methods to characterise this environment in real and modelled situations. In doing so, Jeannin's team hopes to provide a mechanism whereby a variety of stakeholders can apply the obtained information and theoretical models to improve the management of karst aquifers, assuring their sustainability in the context of increasing human activity, interference and utilisation.



How are the karst aquifers organised? Where are the main drainage axes? What is the extension of the catchment? KARSYS is specifically developed to answer these questions.

Management of SwissKarst Waters in Switzerland

Sustainable water management
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